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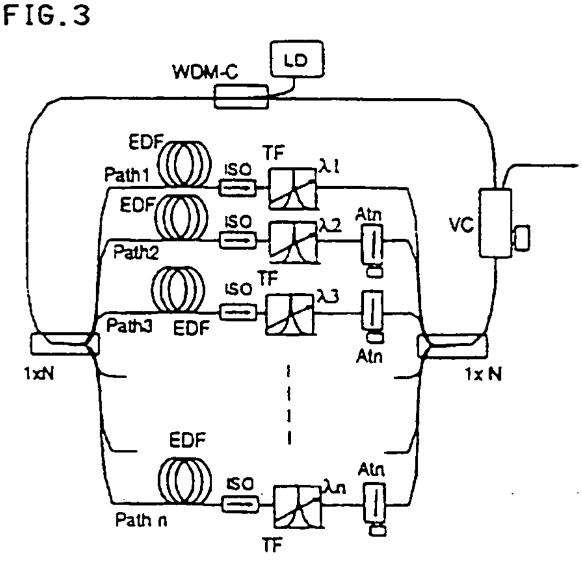
(54) **Wavelength-varying multi-wavelength optical filter laser**

(57) A laser using a single pump light source (LD) is disclosed. The laser comprises a wavelength-division multiplexing coupler (WDM-C) applying an output from a single pump light source into an optical fibre, a first multi-branch optical fiber coupler (1 x N) for branching the light from the single pump light source into a plurality of optical paths, an erbium-doped fiber (EDF) located in each of optical paths, and wavelength-varying optical filters (TF) located at the rear of each erbium-doped fiber in each optical path, the wavelength-varying optical filters acting to generate laser outputs of different wavelengths in each optical path. Optical isolators (ISO) located between the erbium-doped fiber and the wavelength-varying optical filter in each optical path, act to reduce interference between laser outputs to stabilise them, and optic attenuators (Atn) located at the rear of the wavelength-varying optical filter in each optical paths act to regulate mode beating between laser outputs of different wavelengths, thereby allowing multi-wavelength laser oscillation to be possible. A second multi-branch optical fiber coupler (1 x N) couples the branched-optical paths, and a variable optical fiber coupler (VC) located at the rear of the second multi-branch optical fiber, acts to regulate the coupling ratio of the second variable optical fiber coupler, thereby increasing the output thereof.

FIG.3



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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FIG. 1A

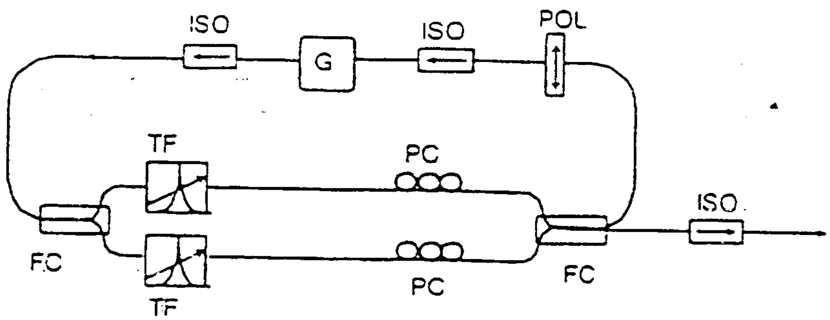
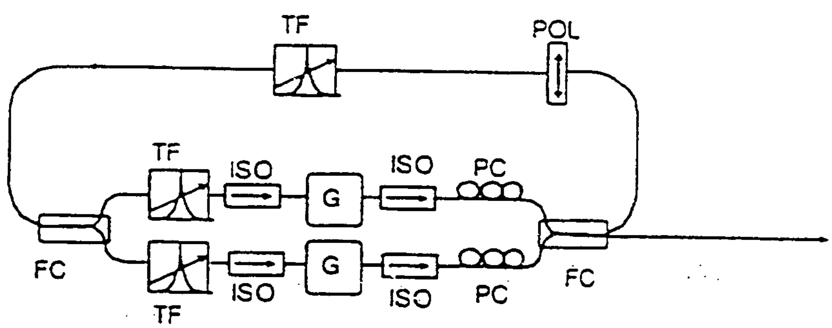

ISO
G
ISO
POL
TF
PC
ISO
FC
PC
FC
TF

FIG. 1B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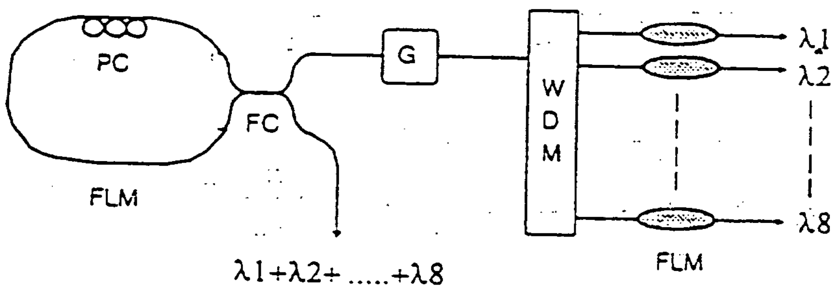
POL
TF
ISO
G
ISO
PC
FC
ISO
G
ISO
PC
FC
TF

FIG.2A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FC
FLM
G
W D M
λ1
λ2
λ8
FLM
λ1+λ2+ .....+λ8

FIG.2B

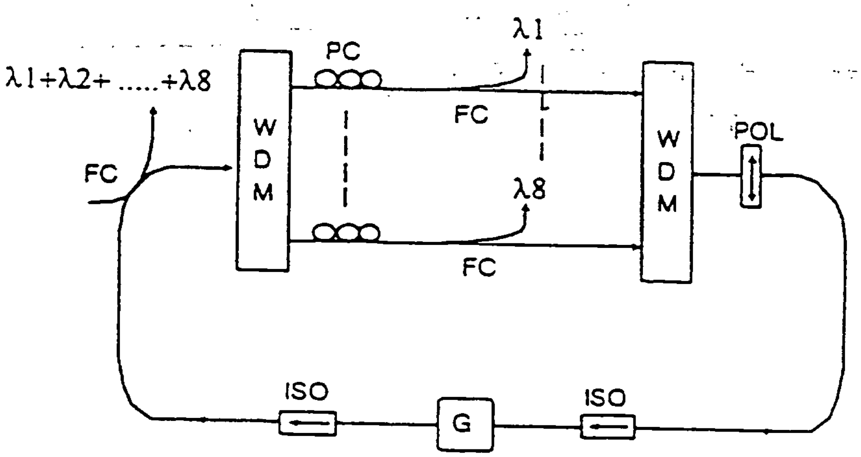
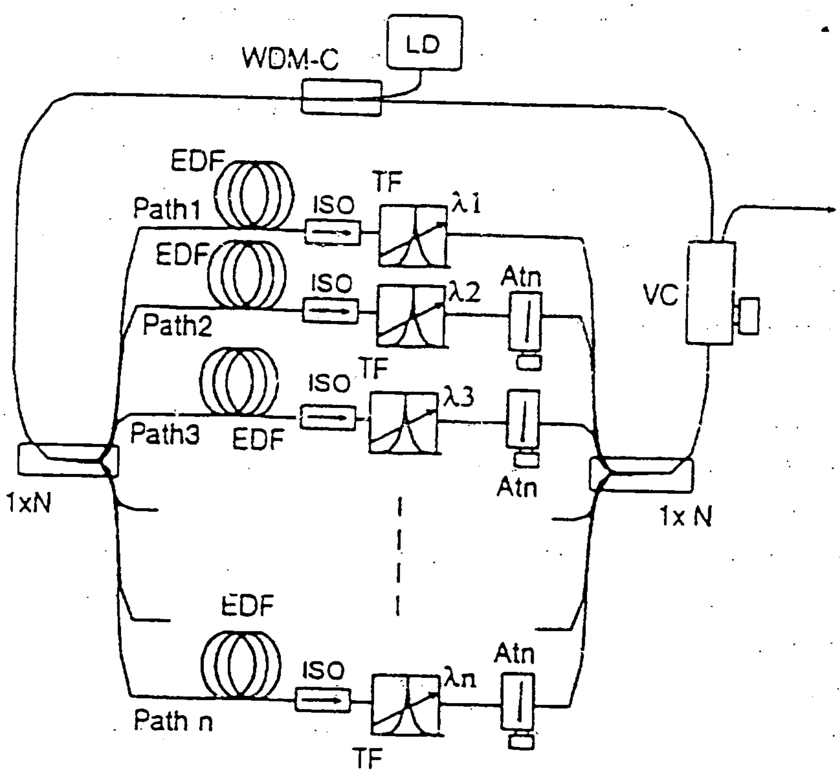

λ1
PC
λ1+λ2+ .....+λ8
FC
W D M
FC
W D M
POL
λ8
FC
ISO
G
ISO

FIG.3


WDM-C
LD
EDF
Path1
ISO
TF
λ1
EDF
ISO
λ2
Atn
Path2
VC
ISO
TF
λ3
Path3
EDF
1xN
Atn
1x N
EDF
Atn
ISO
λn
Path n
TF

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WAVELENGTH-VARYING MULTI-WAVELENGTH OPTICAL FILTER LASER

The present invention relates to a wavelength-varying multi-wavelength light source for use in non-linear effect induction, such as a wavelength-division multiplexing optical communication or 4 optical wave mixing, and more particularly to a wavelength-varying multi-wavelength optical filter laser using a single pump light source capable of converting wavelength.

In general, the need for wavelength-division or frequency-division multiplexing for wide band optical communication has been increasing. Wavelength-varying multi-wavelength light sources play an important role in embodying these multiplexing techniques.

In a wavelength-division or frequency-division multiplexing, an optical fiber laser or a semiconductor laser may be used as a light source which is capable of wavelength conversion or oscillates at different wavelengths.

In order to obtain the desired wavelength, the known semiconductor lasers which are used as a light source oscillating at different wavelengths as above described, may be fabricating in one chip through a complicate process or by constituting a wavelength-varying semiconductor laser.

However, wavelength-varying semiconductor lasers cause problems in that their entire configuration is complicate and even so it is difficult to obtain a multi-wavelength output.

The above problems are explained hereinafter.

Figure 1 of the accompanying drawings shows a diagram illustrating a known wavelength-varying multi-wavelength optical filter laser using a wavelength-varying optical filter. As shown in Figure 1, the known wavelength-varying multi-wavelength optical filter laser uses a polarizer POL and a polarization controller PC laser. However, the prior laser is difficult to extend in multi-wavelengths because it has the instability that the polarization may be change due to even very small distortions of an optical fiber and it has low practicality due to the large bulk of the polarization controller.

Figure 2 of the accompanying drawings shows a known wavelength-varying multi-wavelength optical fiber laser using a wavelength-division multiplexer.

When the wavelength-division multiplexer is originally fabricated, it is usually divided into fixed wavelengths so that the optical fiber laser does not have a wavelength-varying characteristic.

It is also known to provide lasers that make a ring-type optical fiber laser cavity, using a single mode optical fiber containing rare earth elements for gain and a multi-mode optical fiber. These lasers obtain a multi-wavelength laser output using a filter characteristic depending on wavelengths due to spatial mode beating between two basic modes LP_{01} and LP_{11} in the multi-mode optical fiber.

However, this known laser has the problems that the wavelength space of the multi-wavelength laser is controlled in dependence on the length of the multi-mode optical fiber and accordingly has no separate wavelength-varying characteristic for each laser wavelength.

The present invention addresses the problems of the known lasers using a wavelength-varying multi-wavelength light source and seeks to provide a wavelength-varying multi-wavelength optical filter laser using a single pump light source, which has a higher degree of practicality.

Viewed from one aspect the invention provides a wavelength-varying multi-wavelength optical filter laser, comprising:

a single pump light source for generating light;

a wavelength-division multiplexing coupler for applying an output from the single pump light source;

a first multi-branch optical fiber coupler for branching the light from the single pump light source into a plurality of optical paths;

an erbium-doped fiber located in each of the optical paths;

wavelength-varying optical filters located with each erbium-doped fiber in each optical path, said wavelength-varying optical filters acting to generate laser outputs of different wavelengths in each optical path;

optical isolators located between the erbium-doped fiber and the wavelength-varying optical filter in each optical path, said optical isolators acting to reduce interference between laser outputs to aid stability;

optic attenuators located with at least some of the wavelength-varying optical filters in each optical path, said attenuators acting

to regulate mode beating between laser outputs of different wavelengths, thereby facilitating the multi-wavelength laser oscillation;

a second multi-branch optical fiber coupler for coupling the branched-optical paths; and

a variable optical fiber coupler located at the output of the second multi-branch optical fiber, said variable optical fiber coupler acting to regulate a coupling ratio of the second variable optical fiber coupler, thereby increasing the output thereof.

Viewed from another aspect the invention provides a wavelength-varying multi-wavelength optical filter laser comprising:

a pump light source;

an optical fiber receiving light output from said pump light source;

a multiplexer for splitting light in said optical fiber into a plurality of lasing optical fibers each having a wavelength controlling element;

a multiplexer for combining light from said plurality of lasing optical fibers into said optical fiber; and

a coupler for outputting light from said optical fiber.

An embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings.

Figure 1 is a configuration diagram of a known wavelength-varying multi-wavelength optical filter laser using a wavelength-varying optical filter;

Figure 2 is a configuration diagram of a known wavelength-varying multi-wavelength optical filter laser using a wavelength-division multiplexer; and

Figure 3 is a configuration diagram of a wavelength-varying multi-wavelength optical filter laser using a single pump light source.

Figure 3 shows the configuration of a wavelength-varying multi-wavelength optical filter laser using a single pump light source.

Referring to Figure 3, the wavelength-varying multi-wavelength optical filter laser using a single pump light source comprises a single pump light source LD for generating light, a wavelength-division multiplexing coupler WDM-C for applying the output from the single pump light source, a first multi-branch optical fiber coupler 1xN for

branching the light from the single pump light source into a plurality of optical paths, erbium doped fibers (EDFs) which are located at each of the optical paths, wavelength-varying optical filters TFs located at the rear of each of EDF in each optical paths for generating laser outputs of different wavelengths in each optical paths, optical isolators ISOs, which are located between the EDFs and the wavelength-varying optical filters TF in each optical path and reduce interference between laser modes, optic attenuators Atns which are located at the rear of the wavelength-varying optical filter TF in each optical paths and regulate mode beating between laser modes of different wavelengths, thereby causing the multi-wavelength laser oscillation to be possible, a second multi-branch optical fiber coupler 1xN for coupling the branches optical paths, and a variable optical fiber coupler VC which is located at the rear of the second multi-branch optical fiber and regulates a coupling ratio of the laser resonator.

The output from the single pump light source LD is applied to the wavelength-division multiplexing coupler WDM-C to pump the EDFs which are located at each of optical paths branched by the multi-branch optical fiber coupler 1xN. The wavelength-varying optical filters TFs are inserted at each of optical paths, thereby constituting the wavelength-varying multi-wavelength optical fiber laser.

The optical isolators ISOs are used in each of optical paths to reduce interference between laser modes of different wavelengths which oscillate in different paths, so as to make the output of the laser more stable. The optic attenuators Atns are used to regulate mode beating between laser modes of different wavelengths, so that multi-wavelength laser oscillation is possible.

The variable optical fiber coupler VC regulates the coupling ratio of the laser resonator so as to increase the output of the optical fiber laser towards a maximum and to serve as an output terminal.

In one of the plurality of optic paths, the length of EDF may be somewhat smaller or larger than the optimal length compared with other optic paths so slightly reducing the gain characteristics. Accordingly, an optic attenuator Atn is not present in that path, Path1.

The multi-branch optical fiber coupler 1xN has a wide band

characteristic, so providing a device having a comparatively uniform branch characteristic at the pump wavelength and the laser wavelengths and may also be used as the multi-branch optical fiber coupler without dependence upon the state of the other elements.

Devices such as the optical isolator ISO, the wavelength-varying optic filter FT, the optic attenuator Atn, the variable optic filter coupler VC and the wavelength-division multiplexing coupler WMD-C have characteristics unrelated to the deflection (wavelength(s) generated).

According to the above embodiment, a wavelength-varying multi-wavelength laser output can be obtained using a single optical fiber laser. Furthermore, a laser is provided which is capable of improving the laser output characteristics and reducing the number of assembly parts and having a higher utility compared with the known lasers.

Laser outputs of different wavelengths can be independently varied and the wavelength-varying multi-wavelength optic fiber laser may be used as a light source for generating an optic signal of new wavelengths in wavelength-division multiplexing optical communication or 4 optical wave mixing.

Althcugh the preferred embodiments of the invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope of the invention.

CLAIMS

1. A wavelength-varying multi-wavelength optical filter laser, comprising:

a single pump light source for generating light;

a wavelength-division multiplexing coupler for applying an output from the single pump light source;

a first multi-branch optical fiber coupler for branching the light from the single pump light source into a plurality of optical paths;

an erbium-doped fiber located in each of the optical paths;

wavelength-varying optical filters located with each erbium-doped fiber in each optical path, said wavelength-varying optical filters acting to generate laser outputs of different wavelengths in each optical path;

optical isolators located between the erbium-doped fiber and the wavelength-varying optical filter in each optical path, said optical isolators acting to reduce interference between laser outputs to aid stability;

optic attenuators located with at least some of the wavelength-varying optical filters in each optical path, said attenuators acting to regulate mode beating between laser outputs of different wavelengths, thereby facilitating the multi-wavelength laser oscillation;

a second multi-branch optical fiber coupler for coupling the branched-optical paths; and

a variable optical fiber coupler located at the output of the second multi-branch optical fiber, said variable optical fiber coupler acting to regulate a coupling ratio of the second variable optical fiber coupler, thereby increasing the output thereof.

2. A laser as claimed in claim 1, wherein in one of a plurality of optic paths, a length of the erbium-doped fiber is substantially smaller or larger than an optimal length as compared with other optic paths, an optic attenuator Atn not being present in that path.

3. A laser as claimed in any one of claims 1 and 2, wherein the

multi-branch optical fiber couplers have a wide band characteristic.

4. A wavelength-varying multi-wavelength optical filter laser comprising:

a pump light source;

an optical fiber receiving light output from said pump light source;

a multiplexer for splitting light in said optical fiber into a plurality of lasing optical fibers each having a wavelength controlling element;

a multiplexer for combining light from said plurality of lasing optical fibers into said optical fiber; and

a coupler for outputting light from said optical fiber.

5. A wavelength-varying multi-wavelength optical filter laser substantially as hereinbefore described with reference to Figure 3.

Patents Act 1977 **Examiner's report to the Comptroller under Section 17** **(The Search report)**	Application number GB 9425586.6
Relevant Technical Fields (i) UK Cl (Ed.N) H1C (CBAA) (ii) Int Cl (Ed.6) H01S (3/06, 3/08, 3/23)	Search Examiner D MOBBS Date of completion of Search 16 FEBRUARY 1995
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASES: WPI, INSPEC	Documents considered relevant following a search in respect of Claims :- 1-5

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages	Relevant to claim(s)
X	EP 0607868 A1 (ALCATEL SEL) see Figure 4	4
A	US 5309455 (ANDO ELECTRIC) see Figure 4	

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).